BUILDING ENVELOPE TECHNOLOGY SYMPOSIUM

Dual-Sealed Movement Joints in Roofing and Waterproofing Applications

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ABSTRACT

Expansion joints are often the most challenging aspect of roofing or waterproofing membrane system design on both new installations and replacement projects. While the field of the membrane is generally predictable and well detailed by membrane manufacturers, the transition of the membranes at expansion joints can be unique to every project.

When designing expansion joints, dual-seal systems can be considered to provide longer-term waterproofing performance. This approach involves utilizing the roofing and waterproofing membrane as the primary assembly, along with a flexible gland that is compatible with the roofing or waterproofing membrane as the secondary seal.

SPEAKER

Rocco Romero, AIA — Wiss, Janney, Elstner Associates, Inc.

Since joining Wiss, Janney, Elstner Associates, Inc. over 20 years ago, Mr. Romero has been involved in a wide range of investigation and repair projects that include exterior building envelope systems. He has special expertise in the investigation and design of repairs for various waterproofing and roofing systems.

Mr. Romero's recent work includes replacement of the terrace waterproofing systems at the Oregon State Capitol in Salem, OR, and the Washington State Capitol in Olympia, WA; and roofing replacement at the Yale Center for British Art in New Haven, CT, and the Anchorage Museum at Rasmuson Center in Anchorage, AK.

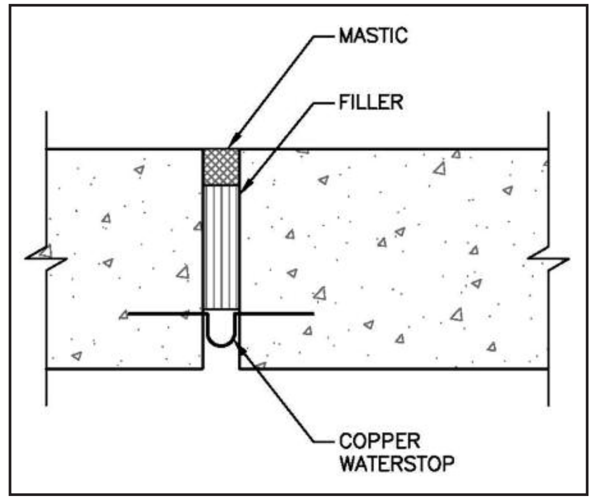
Dual-Sealed Movement Joints in Roofing and Waterproofing Applications

Expansion joints and seismic joints are often the most challenging aspect of roofing or waterproofing membrane system design, both on new installations and as part of replacement projects. While the field of the membrane is generally predictable and well detailed by membrane manufacturers, the transition of the membranes at movement joints can be unique to every project. Close attention to these critical areas is needed to prevent water leakage into the building interior and localized failure of the membrane system. In many waterproofing applications, architectural paving or other architectural finishes make it difficult and expensive to inspect and repair distressed joint assemblies. Proper detailing of these critical conditions is therefore essential to successful long-term performance of the waterproofing system.

When designing the waterproofing aspect of movement joints, dual-seal systems should be considered to provide longer-term waterproof performance. This approach of redundant seals involves utilizing the roofing and waterproofing membrane as the primary assembly and incorporating a flexible gland as the secondary seal. The design for a dual seal should include systems that shed water and, most importantly, that can be adapted to existing conditions.

BACKGROUND

The use of sealed movement joints in buildings is a concept that has developed out of the need to keep joints from allowing water penetration to building interiors or out of water tanks and other structures. Historically, movement joints in horizontal applications used a copper waterstop set into the joint as the waterproofing component of the joint. Laps in the copper waterstop were typically three-quarters of an inch and fully soldered. Semiflexible filler materials were added into the open portion of the joint above the waterstop and capped off flush with the top of the joint with mastic or lead. These semiflexible filler materials included composition asphalt and vegetable fiber, composition asphalt and cork, and asphalt-based compounds that are used as mastics. In concrete slab applications, copper waterstops were installed as a part of the initial concrete placement, with the waterstop flanges cast into the edges of the joint.



In order to accommodate movement, the profile of the copper waterstop required a standing rib or trough; however, troughs could collect infiltrating water and allowed no means for drainage to the building exterior (*Figure 1*). Several designs for flexible, water-resistant plastic waterstops and flashing strips were registered with the United States Patent Office beginning in the early 1940s.

In contemporary design, movement joints are a part of the building envelope and generally occur at seismic joints, expansion joints, and isolation joints. Movement joints in buildings commonly occur at changes in the structural system, between adjacent buildings, and between adjacent, dissimilar building envelope materials. A brief description of movement joints is as follows:

- **Expansion joints** are designed to allow the expansion and contraction of materials and system components, such as expansion of brick masonry and concrete creep, as well as to accommodate thermal movement of materials.
- **Isolation joints** are used to separate systems from each other and extend through the entire building system or assembly. These joints are designed to allow components to move independently of one another and are used to isolate different roofing membrane systems or at the transition of a slab-on-ground to a column footing or adjacent wall.
- **Seismic joints** are wider than expansion and isolation joints and are designed to separate buildings so that the buildings can move independently of one another during seismic activity and minimize damage from building-to-building contact.

While the waterproofing integrity of the assembly is often well designed over the expanse of the roof, foundation, terrace, or plaza, the interface of waterproofing systems with movement joints, which is critical to the overall watertight integrity of the completed system, is often not understood as well. While leaky joints that allow water intrusion into the building's interior space are readily detected and a nuisance, water that infiltrates underneath the roofing membrane or into the exterior wall system may cause undetected and more severe damage and deterioration of building components.

CASE STUDIES

Three case studies of projects where dual-sealed movement joints were designed are presented herein and include both new construction and retrofit designs. These projects include the Oregon State Capitol terrace renovation project in Salem, OR; the Emerald Queen Hotel and Casino new construction project in Fife, WA; and the Anchorage Museum at Rasmuson Center roofing replacement project in Anchorage, AK.

OREGON STATE CAPITOL TERRACE WATERPROOFING RENOVATION PROJECT

The current Oregon State Capitol building was constructed in 1938 in Salem, OR. In 1977, the building was enlarged with new additions, including three office tower wings linked together at the first- and second-floor levels. The second-floor terrace was accessible from the east or west office wings or directly from the governor's office. At the first floor below the terrace, building functions included a public lobby entrance and hearing rooms. The original terrace construction consisted of a structural concrete-composite slab/joist system covered by a waterproofing membrane system, mortar-setting bed, slate pavers sloped to trench drains, and integral concrete planters at the terrace perimeter.

The terrace was originally designed as a structure independent of the Capitol building and adjacent east and west office wings; thus, a seismic joint existed at the perimeter of the terrace on three sides. Water leakage at the seismic joints had infiltrated the membrane flashing, which suffered from adhesive failure at the substrate and passed between the gasket and concrete substrate at the joint interface (*Figure 2*). In this system, the gasket was dry-fitted into the joint and also had gaps along its length at butt joints. While the gasket provided back-up support that allowed the membrane to bridge the width of the joint, the gasket itself was not installed as an independent waterproofing component.

In 2008, as a part of the building renovation, the terrace-level waterproofing system was removed and replaced. The new waterproofing membrane system consisted of a reinforced, hot-applied, rubberized-asphalt membrane system applied to the top of the structural slab, a protection layer, drainage mat, and patterned architectural concrete topping slab sloped to trench drains. In the area of the waterproofing membrane replacement work, all existing gaskets and membranes were removed at the seismic joints.

The new topping slab would limit future access to the waterproofing membrane at the seismic joint; therefore, a dual-seal

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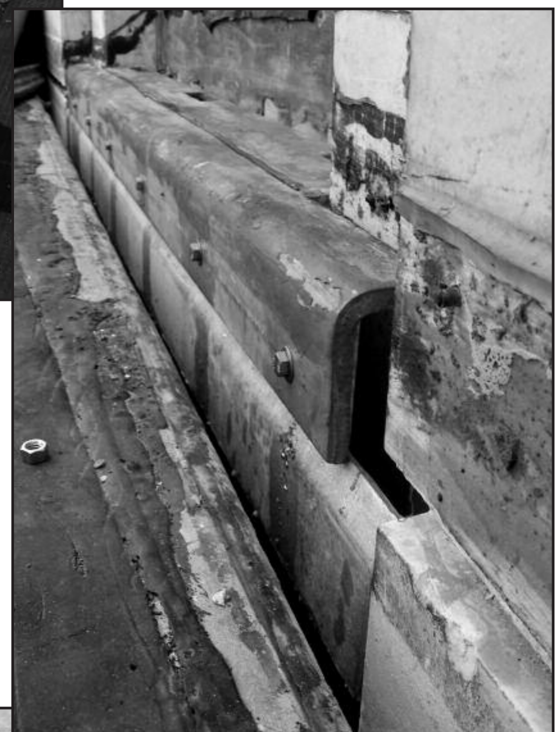

movement-joint approach was used. The design utilized a preformed, acrylic-impregnated expanding foam seal that expands to fill and seal the gap in the joint. This preformed seal was considered to be the second seal or backup line of defense against water intrusion into the seismic joint. The primary seal utilized a flexible gland embedded in a layer of hot-applied rubberized asphalt. Both the waterproofing membrane manufacturer and foam seal manufacturer confirmed prior to installation that the components were compatible with each other.

As with many retrofit projects, unique transitions between buildings required specialized movement-joint waterproofing design. For example, at the north-perimeter planter walls, a seismic joint was located directly below windowsills, with gaps between the existing steel bent-plate marble sill support and existing joint gasket (*Figures 3* and *4*). Removal of the gasket revealed a gap between the lowest edge of the steel bent-plate sill support and the top of the planter wall (*Figure 5*).

In order to install the preformed acrylic-impregnated expanding-foam seal, a new bent-plate extension was fabricated and attached to the existing steel bent-plate sill support (*Figure 6*). Sheet-metal flashing closure components were also fabricated to span gaps so as to support the new flexible gland that became a part of the new waterproofing membrane system (*Figure 7*).

In order to verify adhesion of the new waterproofing membrane system to the various substrates (which included marble, concrete, and steel), the substrates were prepared and primed where applicable, and membrane patches were installed and evaluated (*Figure 8*).

Transitions from horizontal to vertical components required special detailing in order to maintain the watertight integrity of the joint. At the preformed acrylic-impregnated expanding-foam seal, portions of the ends of the vertical and horizontal components were miter-cut at a 45-degree angle and keyed together. The top of the expanding foam was set level with the top edge of the joint to eliminate creation of a trough that could potentially collect infiltrating water. Flexible gland was then installed over the preformed acrylic-impregnated expanding-foam seal in a layer of hot-rubberized asphalt. As a part of the waterproofing membrane system, a membrane flashing was installed directly over the flexible gland in a layer of hot-rubberized asphalt waterproofing. The reinforced waterproofing membrane system was then installed, integrated with the membrane flashing (*Figures 9*, *10*, and *11*).

Another difficult seismic-joint transition occurred where the planter walls terminated at the building's doorway entrances. Because the existing marble was

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keyed into a masonry backup wall, several directional changes occurred in the movement joint. The preformed, acrylic-impregnated expanding-foam seal was field-cut and fit together with mitered corners to provide a waterproof secondary seal. The primary seal flexible gland was installed in a layer of hot-applied rubberized-asphalt waterproofing. Additional flexible gland was installed vertically up the planter at the movement joint in a ship lap manner and set in a layer of hot-applied rubberized asphalt. The reinforced waterproofing membrane system was fully installed and integrated with the flexible gland, creating a monolithic waterproofing membrane system. This construction resulted in a completed assembly that was contoured to the existing condition, and thus not reliant on numerous layers of built-up field laps and splices.

An important aspect of waterproof movement joints is that the vertical flashing component be properly terminated. Water intrusion can occur if a membrane fails adhesively and debonds from its substrate. The installation of fully sealed termination bars at the vertical leading edge of the membrane is recommended for a long-term waterproof joint. The completed horizontal joint system should be successfully flood-tested and monitored, with no leakage for 48 hours, in accordance with ASTM D5957, Standard Guide for Flood-Testing Horizontal Waterproofing Installations.

EMERALD QUEEN HOTEL AND CASINO ROOFING PROJECT

In 2006, the Native American Puyallup Tribe began construction of a new casino and office-tower complex that annexed the north elevation of an existing circa-1980s hotel. A 300-ft-long seismic joint was designed between the existing hotel and new two-story casino addition. The joint was located above occupied building areas.

The new casino roof construction consisted of a composite metal deck, vapor retarder, rigid insulation, and a mechanically attached, reinforced, 60-mil thermoplastic olefin (TPO), single-ply roofing membrane. The roof deck sloped to a drainage trough located adjacent to the seismic joint. The existing hotel exterior-wall construction generally consisted of vertical fluted concrete piers with stucco infill panels and aluminum-framed punched window units and packaged terminal air-conditioner (PTAC) units located directly below the windows. As a part of the limited hotel renovation, the existing through-wall PTAC units were removed and an alternative HVAC system installed, and the PTAC openings were infilled with a stucco wall assembly.

The most challenging aspect of waterproofing design for this movement joint was that the exterior face of the fluted concrete piers and adjacent stucco panels were at different planes and did not align; thus, the seismic joint gap ranged between 2 in at the fluted concrete piers and 6 in along the stucco cladding. In addition, since the stucco cladding was part of the existing hotel exterior wall construction, it continued downward into the seismic joint. Water that infiltrated the stucco system could bypass the seismic joint seals and leak into the building.

In order to address the gap created by the stucco setback at the fluted concrete piers, continuous wood blocking was added to establish a datum line for the termination point of the roofing membrane and provide a substrate to attach components required for the movement joint (*Figure 12*).

Because the stucco cladding continued downward into the movement joint, the stucco assembly required the addition of new flashing above the movement joint. To accomplish this, a strip of stucco was removed. A portion of the existing metal lath and weather-resistive barrier was left in place, and new sheet-metal counterflashing was integrated. The existing weather-resistive barrier of the stucco assembly lapped over the counterflashing, providing a new drainage path and flashing system for the stucco wall system.

The single-ply TPO roofing membrane was utilized as the primary waterproofing component for the movement joint. While the TPO membrane thickness was typically 60 mils in the field of the roof, membrane thickness was reduced to 45 mils at the joint in order to fold the membrane and create slack to accommodate anticipated movement (*Figure 13*).

The folded TPO membrane was terminated vertically at the new blocking. The membrane was installed with a slope-to-drain toward the outside roof edge and into the roof drainage trough.

A sheet-metal joint cover was hooked to a continuous cleat at the roof side of the curb to accommodate movement of the seismic joint. This cover was fabricated with fully soldered corners and sealed at laps to provide a secondary water-shedding component for the joint. Due to the irregular surface of the fluted concrete, a reglet was cut into the concrete surface to act as a

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receiver for the sheet-metal counterflashing. Finally, one-component inside corners were fabricated with all seams soldered watertight to address the transition between the fluted concrete pier and the inset stucco wall panel.

A view of the completed system is shown in *Figure 14*. Several field mock-ups were performed to determine the constructibility of the design and implement changes to accommodate as-built substrate conditions.

ANCHORAGE MUSEUM AT RASMUSON CENTER ROOFING REPLACEMENT PROJECT

The original Anchorage Museum at the Rasmuson Center building was constructed in 1967, and building additions were constructed in 1974, 1982, and 2008. During an investigation, it was determined that the existing seismic joint between the original building and the 1982 building addition was leaking water into the building interior.

As a part of the roofing membrane replacement project for the original 1967 building and the 1974 and 1982 additions, the seismic joint waterproofing system was redesigned. Along portions of the seismic joint, the width of the joint varied from 5 in to more than 18 in. This joint was located directly over occupied building space. In order to prevent warm interior air from flowing into the joint and condensing during the winter months, both a vapor retarder and insulation system were designed for the movement joint.

In order to support the vapor retarder and insulation, an aluminum bent-plate system was designed that incorporated a preformed acrylic-impregnated expanding-foam seal. A fluid-applied elastomeric-waterproofing membrane was designed as the vapor retarder for application over the surface of the bent aluminum plate, followed by the installation of rigid board insulation. The combination of the expanding-foam seal and fluid-applied waterproofing provide the secondary seal for this movement joint.

A single-ply ethylene propylene diene monomer (EPDM) synthetic rubber roofing membrane was selected for the new roofing membrane. It will be used to provide the primary seal at the movement joint, applied over a cover board onto rigid insulation that is sloped toward the roof for drainage. The EPDM membrane was designed to be terminated vertically at the adjacent building. To help provide the necessary slack in the EPDM membrane to accommodate joint movement, the EPDM membrane was designed to be installed over a soft, compressible rod at the vertical-to-horizontal transition. Sheet-metal joint covers and counterflashing were designed with sealed

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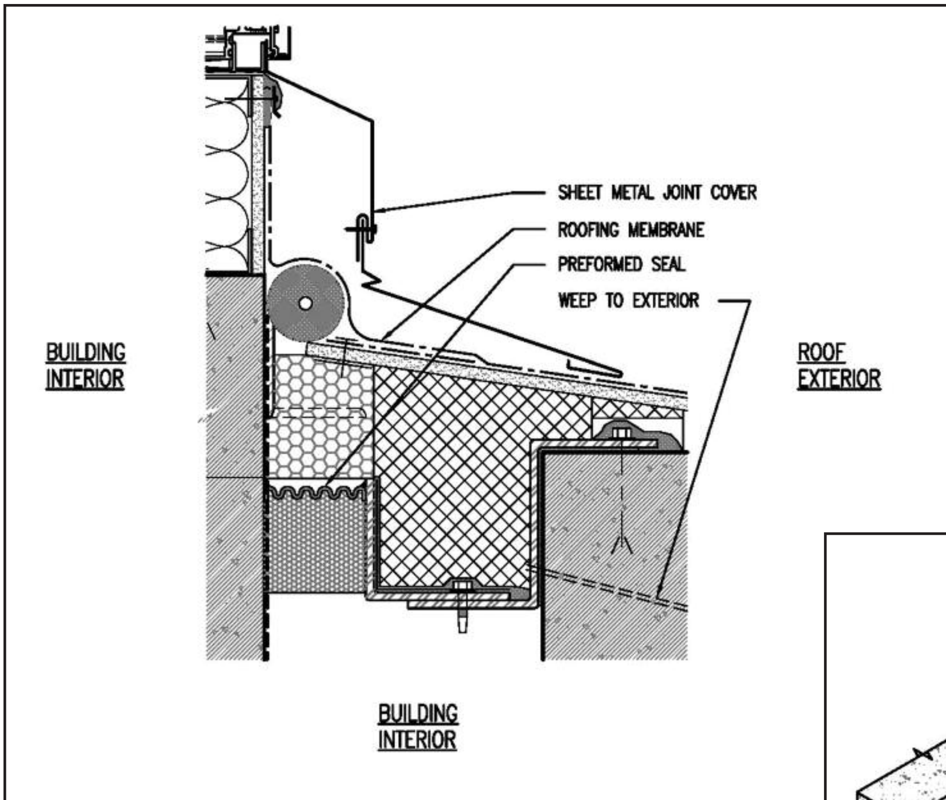

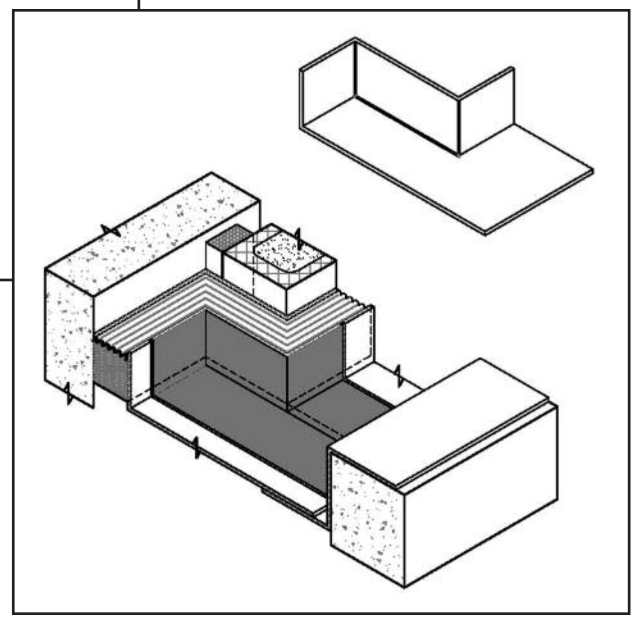

laps to shed water and provide an additional layer of weatherproofing protection (*Figure 15*).

The most challenging aspect of this design was the transition of joint widths along the length of the joint. In this case, the joint width transitions occur at 90-degree directional changes in the joint. In order to maintain the watertight integrity of the joint, the aluminum bent plates were designed with unique inside-to-outside corner components. These components allow the expanding-foam seal to be a continuous width at the corner transitions (*Figure 16*), accommodating movement of the joint. The corner components and bent-plate system were designed to be waterproofed with an elastomeric membrane. The elastomeric membrane will also be an air barrier, preventing building interior airflow from entering the assembly.

CONCLUSIONS

Dual-sealed movement joints can provide longer-term performance and should be considered as an approach to movement-joint waterproofing. The primary and secondary seals should be installed as independent systems that provide a measure of waterproofing independent of one another. If gaskets or preformed foam seals are used as parts of a dual-sealed system, these components should be designed and installed so that they are waterproof yet still allow for the anticipated movement in the joint. Flexible glands and sheet-metal joint covers should also be installed in a waterproof manner, shedding water away from the joint and accommodating movement in the joint. As a resource, ASTM C981, Standard Guide for Design of Built-up Bituminous Membrane Waterproofing Systems for Building Decks, provides general expansion-joint installation guidelines, which include raising the joint above the surface of the deck with the use of curbs.

When retrofitting existing movement joints that are prone to water leakage, waterproofing and roofing systems should be selected that can be designed as integral parts of the joint systems. This approach helps to reduce the number of materials that become part of the assembly, as well as expedites installation by utilizing trades that are on site, performing the waterproofing and roofing work.

One primary advantage to using experienced roofing and waterproofing membrane installers for joint construction is that they have experience in the application of the membrane material and generally also have experience addressing problematic conditions such as inside and outside corner conditions and membrane terminations. Preformed foam seals and flexible glands can be used as part of a redundant waterproof joint, but the materials must be compatible with the other materials with which they come into contact. Prior to implementing a dual-sealed joint, the manufacturers of the components that will make up the joint must review and approve their materials and components as a part of the assembly.

Changes in plane or direction are critical areas of movement-joint design. These areas should be specifically designed as a part of the construction documents for joint-seal installation. These details help identify the need for preformed membrane corners and one-component foam or gland corner components. Detailing of the lap dimensions and treatments, slopes, and terminations is also essential for waterproof joint assemblies.

Mock-ups are an integral and important

part of proper joint installation, and they set the standard for acceptable installation on the project. When selecting a mock-up area, consideration should be given to selecting a typical 90-degree transition, as well as a location that requires changes in plane. It is recommended that mock-ups be performed prior to material being ordered for the entire project, since the purpose of the mock-up is to confirm the constructibility of the joint as designed using the specified materials and to verify that the right materials and sizes have been ordered and delivered for the mock-ups. To evaluate the expertise of the installers, it is recommended that the mock-ups be performed by the same installers who will be performing the work on the project. Mock-ups also provide an opportunity for manufacturers to verify compatibility of component materials, confirm the warranty, and provide additional recommendations. The mock-up period also allows time for the project team to refine details as needed prior to the start of work.

As a part of joint-seal installation in a waterproofing application, the installed joint seals should be water-tested and monitored for leakage in accordance with ASTM D5957, Standard Guide for Flood Testing Horizontal Waterproofing Installations, prior to installation of overburden and concrete-topping slab systems.

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